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EARLY LIFE STUDIES OF LAKE WHITEFISH *(COREGONUS CLUPEAFORMIS)*, CISCO *(COREGONUS ARTEDII)* AND YELLOW PERCH *(PERCA FLAVESCENS)* IN LAKE OPEONGO, ONTARIO

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ABSTRACT

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A program to study the early life stages of lake whitefish (Coregonus clupeaformis), cisco (Coregonus artedii), and yellow perch (Perca flavescens) was undertaken in Lake Opeongo, Ontario, between 1978 and 1980. Daytime surface tows in five index areas provided data on spatial and temporal distribution, and relative abundance and early growth. Additional morphological criteria to aid in the identification of larval cisco and whitefish were determined. Cisco larvae were more numerous and widespread than whitefish. Larval abundance of these species varied among the index areas, but the best catches occurred over, or adjacent to, major spawning areas. Few larval coregonids were taken after surface temperatures attained 12°C. Lake whitefish and cisco emerged from spawning substrates at spring temperatures, which were almost identical to fall spawning temperatures. Perch were first taken in late May in the shallow littoral zones, and progressively later in limnetic areas up to 300–400 m from shore. Larval abundance and growth varied among index areas. A review of the reproduction and early life history of lake whitefish, cisco and yellow perch from Lake Opeongo and several other study areas is presented. Descriptions of the larval stages of four other species are also presented.

Keywords: Lake Opeongo, larval fish, lake whitefish, cisco, yellow perch, reproduction, larval identification, early life studies

EARLY LIFE STUDIES OF LAKE WHITEFISH (Coregonus clupeaformis), CISCO (Coregonus artedii) AND YELLOW PERCH (Perca flavescens) IN LAKE OPEONGO, ONTARIO

INTRODUCTION

It is recognized for many fish species that mortality is greatest during the first year of life (Hempel 1965; LeCren 1965). The principal causes of mortality during early larval stages are believed to be: starvation, predation, toxic substances, and adverse environmental conditions (Braum 1967; Hoagman 1974; May 1974, and others). During the past decade, numerous lakes on the Canadian Shield have shown signs of stressed and declining fish populations due to acid precipitation, which appears to cause excess mortality in early life stages. This problem has intensified the need to better understand the early life history of fish in these lakes.

The current studies were initiated on Lake Opeongo, Algonquin Park, to improve our knowledge of the early life of its fish, particularly the lake whitefish (Coregonus clupeaformis, cisco (Coregonus artedii) and yellow perch (Perca flavescens). The objectives of the program were to describe hatching periods, to determine temporal and spatial distributions of larval stages, to investigate larval growth and abundance, and to determine additional morphological criteria to aid in identifying larval cisco and whitefish.

THE STUDY LAKE

Lake Opeongo, a 58.6 sq km, oligotrophic lake, is the largest in Algonquin Park (Fig. 1). It is located on the Canadian Shield in central Ontario (45°41'N and 78°22'W). The lake has a maximum depth of 52 m, a mean depth of 14.8 m, a pH of 6.76 to 6.90 and an alkalinity of 4.93 to 5.44 mg l^{-1} $CaCO_3$ (M. Swainson, pers. comm.). A comprehensive description of the physical and chemical characteristics of the lake, its watershed and drainage system, is given in Ryder (1964) and Martin and Fry (1973). The shoreline composition of Lake Opeongo is given in Table 1. A list of the fishes known to occur in Lake Opeongo is given in Table 2.

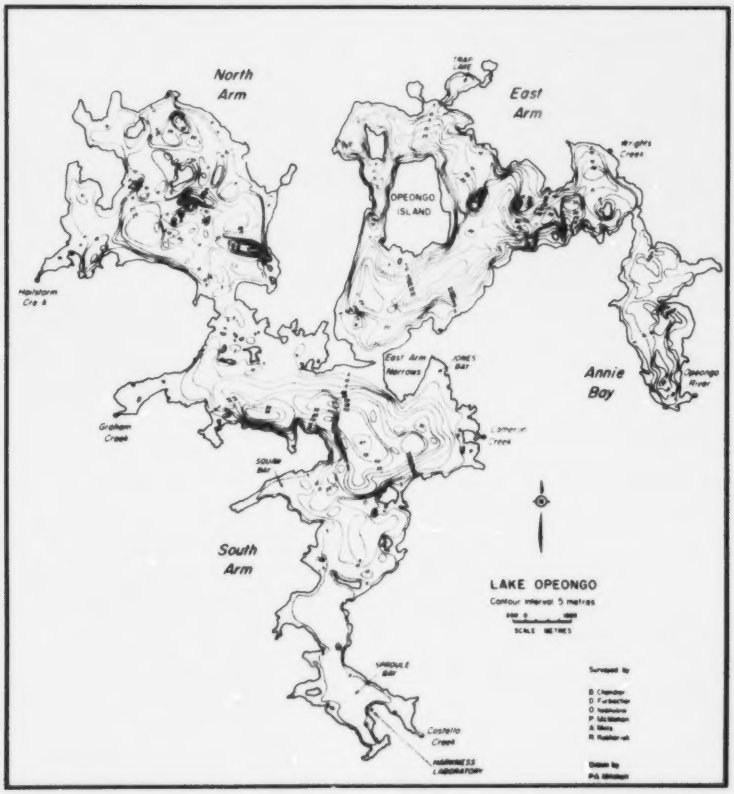

Figure 1. Map of Lake Opeongo, Ontario, showing depth contours and various geographic features.

MATERIALS AND METHODS

FIELD METHODS

The tow net used was slightly modified from that described by Faber (1968). The net opening was 0.5 m^2 in area, the netting material in the front portion was monofilament nylon (1.2 cm stretched measure), the latter portion was of #860 Nitex bolting cloth (0.8 mm mesh), and the collection bucket material of #505 Nitex bolting cloth (0.5 mm mesh).

The towing craft was 5.5 m in length and powered by a 35 hp outboard motor. The boat and single tow net arrangement are shown in Fig. 2. In an attempt to obtain replicate samples, a double tow net system (one on each side of the boat) was tested in 1979. The tow depth was confined to the upper one metre stratum of the lake. Towing speed was set so that the top of the net was 3 to 5 cm below the water surface, which was generally achieved with the motor running at approximately 1400 rpm.

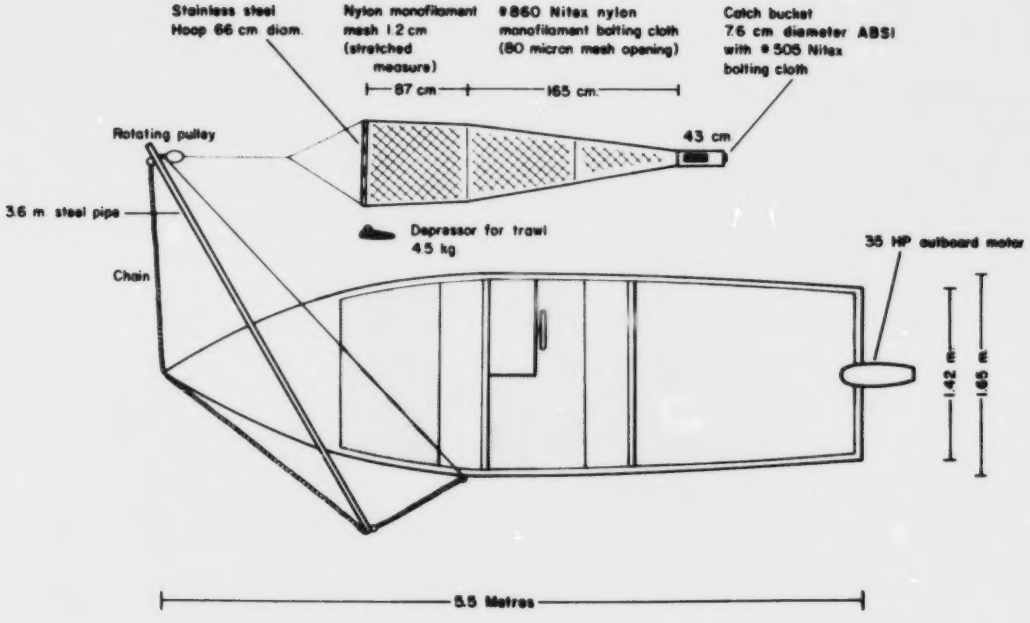

Figure 2. Illustration of boat and single tow net.

Table 1. The percent composition of the shoreline material for the four major lake basins of Lake Opeongo.

Lake basin	Shoreline length* (km)	Sand	Sand, gravel, small boulders	Bedrock, rubble, large boulders	Silt, mud, marsh
South Arm**	49.0	23.6	16.5	41.2	18.7
North Arm	21.1	37.2	26.2	30.7	5.5
East Arm	29.0	30.4	34.9	20.9	13.8
Annie Bay	10.2	17.4	11.1	45.1	26.4

*From N.V. Martin (pers. comm.).
**Does not include the islands of this basin except in the shoreline length.

Table 2. List of fish species occurring in Lake Opeongo[1,2]

Freshwater eels - Anguillidae	
American eel	*Anguilla rostrata* (Lesueur)[3]
Trouts - Salmonidae	
lake herring	*Coregonus artedii* (Lesueur)[4]
lake whitefish	*Coregonus clupeaformis* (Mitchill)
round whitefish	*Prosopium cylindraceum* (Pallas)
brook trout	*Salvelinus fontinalis* (Mitchill)
lake trout	*Salvelinus namaycush* (Walbaum)
splake	*Salvelinus fontinalis* (Mitchill)[5] x *Salvelinus namaycush* (Walbaum)
Minnows - Cyprinidae	
brassy minnow	*Hybognathus hankinsoni* Hubbs
golden shiner	*Notemigonus crysoleucas* (Mitchill)
common shiner	*Notropis cornutus* (Mitchill)
northern redbelly dace	*Phoxinus eos* (Cope)
finescale dace	*Phoxinus neogaeus* Cope
bluntnose minnow	*Pimephales notatus* (Rafinesque)
fathead	*Pimephales promelas* Rafinesque
creek chub	*Semotilus atromaculatus* (Mitchill)
pearl dace	*Semotilus margarita* (Cope)
Suckers - Catostomidae	
longnose sucker	*Catostomus catostomus* (Forster)
white sucker	*Catostomus commersoni* (Lacepède)
Bullhead Catfishes - Ictaluridae	
brown bullhead	*Ictalurus nebulosus* (Lesueur)
Codfishes - Gadidae	
burbot	*Lota lota* (Linnaeus)
Sticklebacks - Gasterosteidae	
brook stickleback	*Culaea inconstans* (Kirtland)
Sunfishes - Centrarchidae	
pumpkinseed	*Lepomis gibbosus* (Linnaeus)
smallmouth bass	*Micropterus dolomieui* Lacepède[5]
Perches - Percidae	
yellow perch	*Perca flavescens* (Mitchill)
Iowa darter	*Etheostoma exile* (Girard)
Sculpins - Cottidae	
slimy sculpin	*Cottus cognatus* Richardson
spoonhead sculpin	*Cottus ricei* (Nelson)

[1] Names after the American Fisheries Society (Robins et al. 1980).
[2] List from Martin and Fry (1973).
[3] Not collected in the last two decades.
[4] Introduced from Mary Lake, Ontario (79°10'W, 45°20'N).
[5] Introduced by Ontario Ministry of Natural Resources.

Preliminary work began in June 1977, to develop procedures suitable for Lake Opeongo conditions. The 1978 program consisted of exploratory tows to search for concentrations of larval whitefish, cisco and perch. From the preliminary data, five widely separated areas which showed consistently good catches of larval fish were chosen as "index areas" (Fig. 3). These index areas received the concentrated sampling effort, and provided the basis for comparisons of larval abundance between areas and between years. A detailed description of the substrate over which index area tows were made is given in Table 3.

Tow netting started as soon as possible after ice break-up.[1] Three tows were made in each index area. In 1978, all three tows were parallel and close to shore and, in 1979 and 1980, two were parallel and one was at right angles to shore (always from shallow to deeper water). Water depths over which tows were made varied from 1.5 to 10 m, but generally averaged 2 to 4 m in tows parallel to shore. Prominent land marks, such as large rocks and points, were used to define the limits of index areas. The average distance travelled during a 5-min tow was estimated from several trials, and was calculated to be 353 $\pm$ 7.0 m. In 1978, tow netting began four days after ice break-up; in 1980, on the day of break-up; and in 1979, 18 days after (due to equipment problems). Samples were taken twice a week in 1978, and 2 to 3 days per week in 1979 and 1980. The number of tows completed during 1978, 1979 and 1980 was 150, 216 and 463, respectively. As time permitted, exploratory runs were made in other regions of the lake to learn more about the spatial distribution of larvae.

At the end of each tow, the cod-end was cleared of any adhering larvae or invertebrate animals, using a pressure-type water sprayer. The contents of the collection bucket were emptied into a plastic container and larvae removed with a kitchen gravy baster. Samples in which larvae were very numerous were preserved in formalin in the field and sorted at the laboratory. Larvae were fixed in a 5 to 10% unbuffered formalin solution and stored in 5% unbuffered formalin. Surface temperatures were taken during each run using a glass hand thermometer. Thermographs at the Harkness Laboratory provided mean daily air and surface water temperatures.

LABORATORY METHODS

Since most sorting was accomplished in the field, laboratory work consisted mainly of identification and measurement of the fish. The seven common fish larvae encountered were separated into five groups: Coregonidae (whitefish and cisco), Percidae (yellow perch, Iowa darter), Gadidae (burbot), Catostomidae (white sucker), and Cyprinidae (several species of minnows). A short key was developed to separate all but the minnows.

In the laboratory, the preserved larvae were placed in a glass dish over a black background and individually picked out with small flexible forceps. The larvae were then put into a small petri dish, identified and measured with a dissecting microscope, and stored in a 5% unbuffered formalin solution.

In 1978, a maximum of 20 larval fish per catch were measured. In 1979 and 1980, all larval fishes caught were measured. For perch larvae, total lengths were measured using needlepoint vernier calipers. For cisco and whitefish larvae, notochord or standard lengths were recorded for better precision. Morphological studies were done on separating cisco and whitefish larvae to make them more easily identifiable.

In the earliest year, a greater effort was expanded in locations other than those finally chosen to be the index areas. In latter years, effort doubled in index areas, because of the reliability and convenience of catching larvae there. Data from all years were presented to show the temporal regime of larval fish, the relative number caught in various index areas, and growth of larval fish during the sampling season. The 1980 data were the most complete. Growth curves for larval whitefish and cisco are for 1980, while growth for perch is presented for 1979 and 1980.

Catch per unit of effort (CUE) for an index area represents the mean number of larval fish caught per 5-min tow, combining all the tows in that particular area for a 3-day time period. The 1979 data (derived from the double net system) were adjusted so that the volume filtered would equal that filtered in a 5-min tow using a single net. Measurement data from all areas were combined to calculate the length and growth data for cisco and whitefish. For larval perch, comparisons were made between index areas and years (1979 and 1980). Relative growth was used to describe early larval growth, because it best describes the rapid growth of this life stage. Relative growth, as used here, is defined as the gain in length during the time period, compared to the length at the beginning of the time period (Everhart and Youngs 1981).

DISTRIBUTION, RELATIVE ABUNDANCE AND GROWTH

During the period 1978-80, 829 tows from 97 separate locations were made in Lake Opeongo, principally in the south and east arms (Fig. 3). The total numbers of larval fish taken were 513 whitefish, 1928 cisco, 4650 perch and 429 other specimens generally too damaged to identify. Larval cisco and whitefish appeared in the catches the first 3 to 4 weeks of May, while larval perch were taken from the last week of May to the first week of July. The time periods and temperatures during which larval whitefish, cisco and perch were taken are presented in Fig. 4.

[1] Ice break-up was defined as the day on which all arms of Lake Opeongo were completely free of ice, or at least easily navigable by small boats.

Figure 3. Larval tow net sites (including both index and exploratory) in Lake Opeongo used during 1978 to 1980. Individual tows are represented by short dashed lines which show the general direction and duration. Sites representing index areas A, B, C, D and E are described in Table 3.

Table 3. Bottom description of tow sites in each index area, and the site's exposure to the prevailing winds.

Index	Tow #	Exposure	Bottom description
A	A1	Open	Rugged bottom with rocky shoreline (4-10 cm boulders) and scattered, sunken logs. Exposed to northerly winds.
	A2	Open	Similar to A1 except that the latter half becomes more sandy. Some scattered, sunken logs present.
	A3.A4	Open	Perpendicular to A2, proceeds from shallow to deep water. Bottom mainly sandy.
B	B1	Protected Bay	Flat, sandy bottom, few sunken logs and scattered small rocks near shore. Quiet sheltered area.
	B2	Open	South portion is flat and sandy, similar to B1. North portion is a rocky, gravel shore (leads into lake trout spawning grounds).
	B3.B5	Open	Runs perpendicular to B2 into deeper waters, bottom is principally sand and mud.
C	C1	Protected Bay	North portion is flat with sandy and silty bottom. South portion is a rugged area with a rocky shoal.
	C2	Open	Rocky shoal area (5-20 cm rocks). Shore slopes quickly down to 3-4 m. Part of a lake trout spawning area. Exposed constantly to prevailing westerly winds.
	C3	Open	Perpendicular to C2 into deeper waters where the bottom is principally mud.
D	D1	Protected Bay	Quiet, protected area where many sunken logs line the shoreline. Sandy bottom with much aquatic vegetation along the shore.
	D2	Protected	Between the mainland and Opeongo Island, starts in shallow, sandy area and proceeds to deeper water.
	D3.D5	Protected	Between the mainland and Opeongo Island, principally over deeper water, bottom mainly mud.
	BB	Protected	West side of Opeongo Island along a shore having a flat, sandy, silty bottom and numerous sunken logs.
	D4	Protected	Rocky shore including a gravel shoal.
	DD	Protected	Sandy, silty shoreline lined with many sunken logs.
E	E1	Protected Bay	Rocky, steep drop-off with large rocks and sunken logs along the shore.
	E2	Protected Bay	Sandy bottom with smaller boulders and fallen trees lining the shore.
	E3	Protected Bay	Sandy bottom with small boulders and sunken logs along the shore.

LAKE WHITEFISH

Larval whitefish were caught along with larval cisco at all index areas, but results from exploratory tows suggested that whitefish were generally not as numerous or as widespread as cisco. On the day of ice break-up (April 29, 1980), exploratory tows made in the index areas caught no larval fish. The earliest whitefish were taken five days after ice break-up in 1978 and three days after in 1980 (Table 4). Surface temperatures at these times varied from 5 to 8°C. In 1980, most of the whitefish were taken between 3 and 23 days after ice break-up when surface temperatures ranged from 6.5 to 10°C. Larval whitefish were present in slightly larger numbers in tows perpendicular to shore than those parallel to shore (Table 5). The highest CUE's for larval whitefish were 2.42 in 1979 and 2.47 in 1980. The largest numbers of whitefish (i.e. CUE) were taken at index areas C and D (Table 6). Occasional whitefish continued to be caught until the end of May and early June when surface temperatures exceeded 12°C.

Larval whitefish caught earliest (May 1, 1980) averaged 11.32 ± 0.61 mm, and were mostly past the yolk stage with a few at the medium yolk stage. During the period of peak abundance, between May 12-16, 1980, larval whitefish averaged 13.00 ± 1.07 mm in length (Fig. 5), had no yolk, and had developed a flexed notochord. The few whitefish caught in mid-June averaged 19.2 ± 2.78 mm in length and possessed pelvic buds. Growth estimates of larval whitefish, particularly in the latter part of the sampling period, are likely biased by the change in the efficiency of the tow net, and also by the behavior of the fish. The older and larger larvae are able to swim fast and more easily avoid the trawl, and they no longer frequent the warm surface layers.

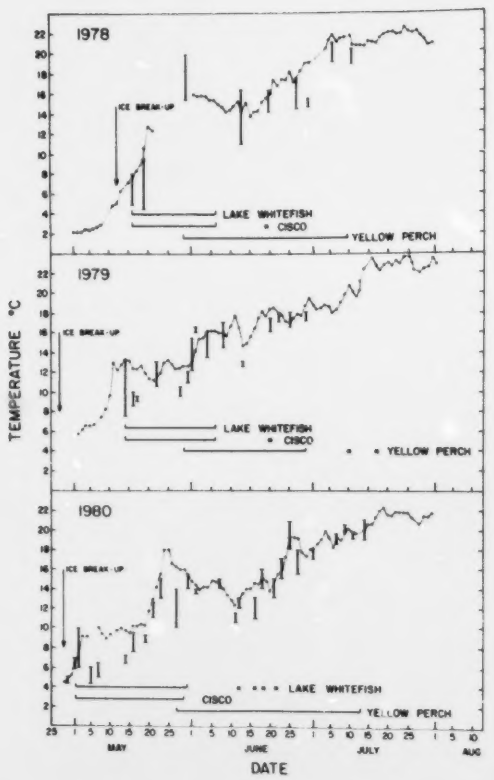

Figure 4. Temporal distribution of larval fish in relation to surface temperatures, 1978-80. Horizontal bars and asterisks indicate period of occurrence of larval fish. Vertical bars indicate range of temperature at index areas. Dotted lines are the mean daily surface temperatures recorded at the Harkness Laboratory.

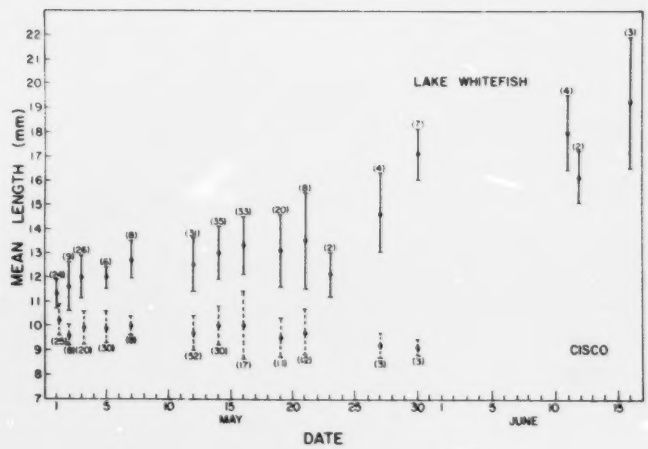

Figure 5. Growth of larval lake whitefish and cisco in Lake Opeongo in 1980. Data from all areas combined. Dots are means and vertical lines are SDs. Numbers in brackets are numbers of larvae measured.

Table 4. Number of larval whitefish, effort (no. of 5 min. tows) and catch per unit of effort (CUE) in Lake Opeongo during 1978-1980.

Sample period	1978			1979			1980		
	No.	Effort	CUE	No.	Effort	CUE	No.	Effort	CUE
Apr 25-27					[1a]				
28-30								[1b]	
May 1-3							35	29.0	1.21
4-6							8	14.0	0.57
7-9							11	14.0	0.79
10-12		[1c]					33	15.0	2.20
13-15				2	5.6	0.36	42	17.0	2.47
16-18	19	18.8	1.01	83	34.3	2.42	36	17.0	2.12
19-21							30	30.0	1.00
22-24	9	4.0	2.25	35	20.2	1.73	2	15.0	0.13
25-27							6	15.0	0.40
28-30	0	5.6	0	16	40.5	0.40	6	15.0	0.40
31/2							1	17.0	0.06
Jun 3-5				0	20.0	0			
Total[2]	28	28.4	0.99	136	120.6	1.13	210	198.0	1.06

[1a]April 27; [1b]April 29; [1c]May 12: dates of ice-out.
[2]Data from all index areas combined.

Table 5. Number of larval whitefish caught at each tow site in Index Areas during 1980.

Date	Index Areas															No. of larvae	No. tows	CUE
	A			B			C			D			E					
	1[a]	2[a]	3[b]	1[a]	2[a]	3[b]	1[a]	2[a]	3[b]	1[a]	2[b]	3[b]	1[a]	2[a]	3[a]			
May 1-3	0	0	0	0	1	0	0	2	2	0	3	21	3	2	1	35	29	1.21
4-6	0	2	0	0	1	1	0	0	0	2	0	1	1	0		8	14	0.57
7-9	0	0	0	1	0	1	0	2	1	5	1	0	0	0	0	11	14	0.79
10-12	3	2	3	0	0	0	0	9	10	2	0	0	1	0	3	33	15	2.20
13-15	1	0	2	0	0	0	0	11	18	5	3	2	0	0	0	42	17	2.47
16-18	1	0	0	0	1	0	8	13	10	0	1	2	0	0	0	36	17	2.12
19-21	0	0	1	0	0	2	0	0	2	4	3	12	2	2	2	30	30	1.00
22-24	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	15	0.13
25-27	1	0	0	1	0	0	0	1	1	1	0	0	0	1	0	6	15	0.40
28-30	0	0	0	0	0	0	0	0	1	3	1	0	0	1	0	6	15	0.40
31-2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	17	0.06
Totals	6	4	6	2	3	4	8	38	46	22	12	38	9	6	6	210	198	1.06

[a]Tow parallel to shore.
[b]Tow perpendicular to shore.

Table 6. Number of larvae, effort (No. of 5 min. tows) and catch per unit of effort (CUE) for cisco, whitefish and perch at Index Areas A, B, C, D and E during 1978-1980.

		Cisco			Whitefish			Perch		
Index Area	Year	No. of larvae	No. tows	CUE	No. of larvae	No. tows	CUE	No. of larvae	No. tows	CUE
A	1978	11	3.6	3.06	2	3.6	0.56	189	11.3	16.72
	1979	1	14.3	0.07	1	14.3	0.07	156	28.1	5.55
	1980	44	37.0	1.19	16	37.0	0.43	774	59.0	13.12
B	1978	70	8.4	8.33	7	8.4	0.83	41	10.0	4.10
	1979	28	24.8	1.13	0	24.8	0	94	45.2	2.08
	1980	22	41.0	0.54	9	41.0	0.22	325	58.0	5.60
C	1978	10	6.4	1.56	8	6.4	1.25	40	9.8	4.08
	1979	90	25.3	3.56	86	25.3	3.40	110	42.2	2.61
	1980	49	41.0	1.20	92	41.0	2.24	195	57.0	3.42
D	1978	97	6.0	16.17	11	6.0	1.83	-	-	-
	1979	154	35.1	4.39	41	35.1	1.17	70	35.0	2.00
	1980	72	41.0	1.76	72	41.0	1.76	242	57.0	4.25
E	1978	33	4.0	8.25	0	4.0	0	56	15.6	3.59
	1979	15	21.1	0.71	8	21.1	0.38	87	32.2	2.70
	1980	57	38.0	1.50	21	38.0	0.55	152	52.0	2.92
Totals	1978	221	28.4	7.78	28	28.4	0.99	326	46.7	6.98
	1979	288	120.6	2.39	136	120.6	1.13	517	182.7	2.83
	1980	244	198.0	1.23	210	198.0	1.06	1688	283.0	5.96

CISCO

As with the whitefish, no larval cisco were taken on the day of ice break-up in 1980. Cisco were first taken five days after break-up in 1978 and three days after in 1980. Larval cisco were caught both in tows parallel to shore and at right angles to shore but, with the exception of two tows in index area D, those made over deep water within the first several days caught few or no fish (Table 7). Cisco were widespread, occurring in many inshore areas where exploratory tows were made, however, in the index areas, they were generally more abundant (i.e. CUE) at index areas C, D and E (Table 8).

The peak CUE's, 5.80 and 5.89 in 1979, and 3.79 and 3.80 in 1980, occurred within 20 and 7 days, respectively, of ice-out (Table 7). Temperatures over these periods were between 6.5 and 9.0°C. Small numbers of larval cisco continued to be caught up to the end of May when temperatures exceeded 12°C.

The length of cisco in the earliest catches averaged 10.26 ± 0.67 mm and ranged from 9.0 to 11.5 mm (Fig. 5). These were at early stages of development - newly hatched with large, medium and small yolk sacs. When peak numbers were caught (May 5-14, 1980), most larvae were in the large yolk stage and averaged 9.7 mm in length. A few appeared to be recently hatched and generally smaller. Large yolk sac larvae continued to be caught until the end of May, suggesting that hatching occurs over a period of 3 to 4 weeks. The longest cisco taken was 12.5 mm. Several biases affect estimates of growth. Because hatching occurs over a period of several weeks, the continual recruitment of smaller larvae underestimates the mean length over that period. Also, towards the latter portion of the sampling period, the gear is less efficient in capturing the longer larval fish which tend to swim faster and occupy other habitats.

Table 7. Number of larval cisco, effort (no. of 5 min. tows) and catch per unit of effort (CUE) in Lake Opeongo during 1978-1980.

Sample period	1978			1979			1980		
	No.	Effort	CUE	No.	Effort	CUE	No.	Effort	CUE
Apr 25-27					[1a]				
28-30								[1b]	
May 1-3							33	29.0	1.14
4-6							53	14.0	3.79
7-9		[1c]					14	14.0	1.00
10-12							57	15.0	3.80
13-15				33	5.6	5.89	33	17.0	1.94
16-18	209	18.8	11.12	199	34.3	5.80	18	17.0	1.06
19-21							27	30.0	0.90
22-24	12	4.0	3.00	34	20.2	1.68	3	15.0	0.20
25-27							3	15.0	0.20
28-30	0	5.6	0	21	40.5	0.52	3	15.0	0.20
31/2							0	17.0	0
Jun 3-5				1	20.0	0.05			
Total[2]	221	28.4	7.78	288	120.6	2.39	244	198.0	1.23

[1a]April 27; [1b]April 29; [1c]May 12: dates of ice-out.
[2]Data from all index areas combined.

Table 8. Number of larval cisco caught at each tow site in Index Areas during 1980.

Date	Index Areas															No. of larvae	No. tows	CUE
	A			B			C			D			E					
	1[a]	2[a]	3[b]	1[a]	2[a]	3[b]	1[a]	2[a]	3[b]	1[a]	2[b]	3[b]	1[a]	1[a]	3[a]			
May 1-3	0	0	0	0	0	0	0	1	4	2	1	19	4	0	2	33	29	1.14
4-6	1	3	2	0	3	0	0	0	1	2	2	14	23	2		53	14	3.79
7-9	0	1	0	0	1	1	0	2	0	5	3	0	0	1		14	14	1.00
10-12	13	3	9	2	0	0	0	9	6	1	0	2	2	4	6	57	15	3.80
13-15	0	1	0	2	1	3	3	2	9	7	0	2	1	0	2	33	17	1.94
16-18	6	1	0	1	1	0	0	2	2	2	0	2	0	1	0	18	17	1.06
19-21	0	3	0	1	1	3	1	2	4	3	2	2	2	1	2	27	30	0.90
22-24	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	3	15	0.20
25-27	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	3	15	0.20
28-30	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	3	15	0.20
31-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0.00
Totals	21	12	11	6	7	9	5	18	26	22	9	41	35	9	13	244	198	1.23

[a]Tow parallel to shore.
[b]Tow perpendicular to shore.

YELLOW PERCH

Exploratory tows showed that larval perch appeared to be widespread around the lake except over deep waters. Larvae were taken in a variety of habitats including rocky, sandy and silt substrates, and along both sheltered and exposed shorelines. Larval perch were first collected in shallow littoral areas and, shortly afterward, in limnetic areas as well. These limnetic areas often extended 300 to 400 m from shore, but usually did not exceed 10 m in depth. Tows parallel to shore over shallow littoral zones produced more larval perch than tows perpendicular to shore (Table 9). However, in two index areas during periods of peak abundance, the average number of larval perch caught in offshore tows equalled the average number caught in inshore tows.

Larval perch were first taken in tows during the latter part of May, just prior to the end of larval cisco and whitefish abundance. Surface temperatures ranged from 12 to 15°C. Perch first appeared in index areas A and E, and shortly afterwards in others. They were captured up to mid-July with peak numbers occurring during the third week of June (Table 10) when temperatures were between 15 to 19°C. Peak numbers of larval perch occurred concurrently in all index areas, with area A having several additional higher catches prior to or following peak periods (Table 9). Combined data from all index areas showed that in 1979, there were two peaks of abundance in the periods June 3-5 and June 18-20, when the CUE was 7.24 and 8.64, respectively (Table 10). Similarly, in 1980, there were two peaks of abundance in the periods June 18-20 and June 24-26, when CUE's were 18.6 and 22.3, respectively. These peak catches appeared 5 to 7 days after short periods of cooler surface temperatures. Abundance varied in different areas of the lake but, in all years, area A had the largest numbers of perch (Table 6).

The first larval perch taken ranged from 5.8 to 8.2 mm in length (Fig. 6). Various yolk sizes were present at this time, but most were medium or small. Mean lengths in offshore tows were slightly less than those for inshore tows. From early to mid-June, growth appeared to be similar in all index areas, with mean lengths in 1979 ranging from 9 to 11 mm, and in 1980 from 9.5 to 11 mm. During the period of peak abundance (usually the third week of June), perch lengths ranged from 13.5 to 14.2 mm in 1979, and from 11.5 to 12.5 mm in 1980. During and following periods of peak catches, an influx of small yolk sac perch appeared, suggesting a secondary hatch. Growth from mid-June to early July appeared best in areas A and D, and poorest in area E (Fig. 6). The longest perch caught measured 18.5 mm in length. The biases experienced, in estimation of mean lengths and growth with larval cisco and whitefish, also apply to larval perch.

The combined data showed relative growth to be better in 1979 than in 1980, but growth prior to June 10 appeared better in 1980 while growth subsequent to June 10 appeared better in 1979. The relative growth rate over the entire sampling period was calculated at 1.569 (1979) and 0.811 (1980). The sum of the mean daily surface temperatures (May 15 to June 10) was greater for 1980 than 1979 - 375 degree days (1980) to 362 degree days (1979). However, for the period June 10-30, the relative growth for perch was greater for 1979 than for 1980, possibly a response to the higher accumulated temperatures - 270 degree days (1979) to 244 degree days (1980).

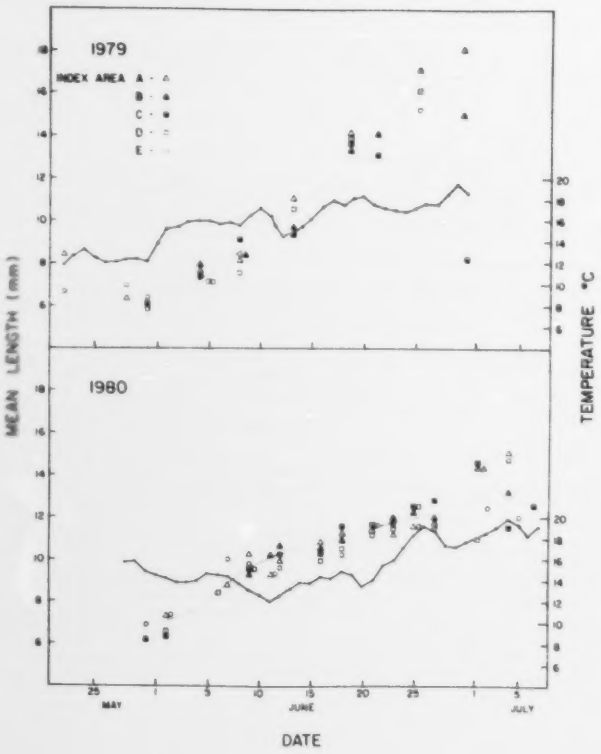

Figure 6. Mean length of larval yellow perch at one of the five index areas in Lake Opeongo for May to July 1979 and 1980. Growth curve, fitted by eye, combines data from all index areas. Mean daily water temperatures are indicated by solid line.

Table 9. Number of larval perch caught at each tow site in Index Areas during 1980.

Date	Index Areas A 1[a]	A 2[a]	A 3[b]	B 1[a]	B 2[a]	B 3[b]	C 1[a]	C 2[a]	C 3[b]	D 1[a]	D 2[b]	D 3[b]	E 1[a]	E 2[a]	E 3[a]	No. of larvae	No. tows	CUE
May 25-27	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-	1	15	0.07
28-30	4	6	3	0	0	0	0	3	0	1	1	0	1	3	0	22	17	1.29
31-2	1	5	6	0	0	0	0	0	3	5	0	5	0	2	1	28	17	1.65
Jun 3-5																		
6-8	3	0	0	0	0	0	0	0	0	5	0	2	0	2	1	13	15	0.87
9-11	2	0	6	10	0	14	7	0	1	0	0	2	3	3	1	49	30	1.63
12-14	7	3	2	11	8	6	1	2	0	0	0	1	2	2	2	47	15	3.13
15-17	15	83	35	6	2	3	4	6	1	7	0	5				167	11	15.18
18-20	35	133	42	3	4	16	2	4	2	2	12	3	16	5	-	279	15	18.60
21-23	10	84	83	28	38	52	24	12	13	57	27	29	6	35	22	520	31	16.77
24-26	81	16	12	62	25	11	45	23	8	30	10	2	2	4	5	336	15	22.33
27-29	3	9	8	3	3	2	14	2	1	1	0	0	0	1	5	52	15	3.47
30-2	1	5	0	4	1	2	0	0	1	7	3	3	0	6	2	35	15	2.33
Jul 3-5	10	52	2	0	1	2	2	5	0	5	0	0	0	1	-	80	14	5.71
6-8	2	2	3	1	0	0	0	0	2	4	6	4	3	2	7	36	15	2.40
9-11	0	0	0	2	1	3	1	4	1	0	1	1	1	1	0	16	30	0.53
12-14	0	1	0	0	0	0	1	0	0	0	1	0	2	2	0	7	15	0.47
Totals	174	399	202	130	83	112	101	61	33	124	61	57	36	69	46	1688	285	5.96

[a]Tow parallel to shore.
[b]Tow perpendicular to shore.

Table 10. Number of larval perch, effort (no. of 5 min. tows) and catch per unit of effort (CUE) in Lake Opeongo during 1978-1980.

Sample period	1978 No.	1978 Effort	1978 CUE	1979 No.	1979 Effort	1979 CUE	1980 No.	1980 Effort	1980 CUE
May 22-24				9	20.2	0.45			
25-27							1	15.0	0.07
28-30				67	40.4	1.66	22	15.0	1.47
31/2							28	17.0	1.65
Jun 3-5				142	19.6	7.24			
6-8	76	7.7	9.87	52	19.6	2.65	13	15.0	0.87
9-11							49	30.0	1.63
12-14	64	4.0	16.00	29	13.1	2.21	47	15.0	3.13
15-17							167	11.0	15.18
18-20	78	7.4	10.54	133	15.4	8.64	279	15.0	18.60
21-23				42	11.2	3.75	520	31.0	16.77
24-26	101	12.0	8.42	29	19.6	1.48	336	15.0	22.33
27-29				7	19.4	0.36	52	15.0	3.47
30/2							35	15.0	2.33
Jul 3-5	4	7.4	0.54				80	14.0	5.71
6-8							36	15.0	2.40
9-11	3	8.2	0.37				16	30.0	0.53
12-14							7	15.0	0.47
15-17				7	4.2	1.66			
Total[1]	326	46.7	6.98	517	182.7	2.83	1688	283.0	5.96

[1]Data from all index areas combined.

INCIDENTAL SPECIES

Larvae of several other species were captured with larval whitefish, cisco and yellow perch. Burbot larvae were caught immediately over and adjacent to known lake trout spawning areas (index areas B and C), west of the East Arm narrows (Loc HH) and in Squaw Bay (Loc E1) (Fig. 3). Larval white suckers were found in areas adjacent to Wrights Creek (Loc U, ZZ); the north and west areas of the East Arm (index areas C, D and Loc AA, EE1, EE2, PP); index area B; and in Loc HH and E5 in the South Arm (Fig. 3).

Small numbers of larval Iowa darters were taken during late June and early July. Early exploratory tows showed that they occurred in separated areas of the lake, with only small numbers being taken in index areas. They were taken in shallow, sheltered bays or along shorelines with sandy or boulder substrate interspersed with aquatic vegetation. The only other kind collected was larval cyprinids which were unidentifiable to species. In July 1982, a light trap was used on several nights in Squaw Bay in 0.5 m depth. Numerous larval bluntnose minnows and a few larval Iowa darters were captured. This light trap experiment supports the general knowledge that cyprinid larvae are more abundant in very shallow littoral areas where our tow net did not sample.

IDENTIFICATION OF CISCO AND LAKE WHITEFISH

Three fishes within the sub-family Coregoninae occur in Lake Opeongo, lake herring or cisco, lake whitefish and dwarf lake whitefish (Kennedy 1943). The collection of wild larvae in Lake Opeongo resulted in a collection of specimens which were not clearly one species or the other. Extensive discussions about the taxonomic status of species within this sub-family (Lindsey et al. 1970; McPhail and Lindsey 1970; Scott and Crossman 1973) suggest there is considerable variation in adult morphology from lake to lake. It is not known what morphological variations their larvae exhibit, but some variations must be present.

After examining several samples, it became obvious that the larvae of whitefish and cisco from Lake Opeongo were morphologically similar. For this reason, considerable effort was expended to develop specific identification criteria to separate the two species. There were no specimens that we assigned as dwarf whitefish although, in fact, there may have been some in our collection. External morphological characteristics of whitefish and cisco larvae were carefully examined, in order to determine criteria for identification. Only the 1979 and 1980 collections were used for these studies. In addition to wild larvae, hatchery raised lake whitefish were examined from Lake Opeongo, Lake Simcoe and South Bay, Lake Huron. We are aware that, in certain species of fish, the size of larvae at hatching varies somewhat with the time of hatching, i.e. late hatched larvae are slightly longer than early hatched larvae, but we did not examine this relationship.

The relationship between notochord length (NL, the length from the tip of the snout to the tip of the notochord) and the amount of yolk (relative size of yolk sac) was determined for the two species. Yolk was recorded as four arbitrary categories, i.e. (1) large yolk, (2) medium yolk, (3) small yolk, (4) no yolk. These comparisons did not produce any significant morphological differences. Large spherical yolk sacs predominated on cisco larvae, while such yolk sacs were never observed on wild whitefish larvae. Hinrichs (1979) observed in an aquarium that both cisco and whitefish began swimming immediately after hatching, so our observations suggest that cisco moved up from the bottom and became free-swimming with larger yolk sacs than whitefish.

The relation between length (NL) and body depth at anus, and the occurrence of caudal fin rays was examined. It was determined that the body depth at anus ranged from 0.4 to 0.7 mm for cisco and 0.6 to 0.7 mm for whitefish for the lengths captured. An overlap occurred between the two species at a notochord length of 10 to 11 mm. Next, the length (NL) versus the number of caudal fin rays appearing in the ventral portion of the caudal fin fold was compared. Again, an overlap occurred between the two species at notochord lengths of 10 to 11 mm.

Next, the relation between notochord length and pre-anal and post-anal lengths were examined. An overlap occurred at notochord lengths of 10 to 11.5 mm (Fig. 7). This figure indicates that cisco larvae were collected at lengths ranging from 7.5 to 11.5 mm, whereas whitefish larvae were collected at lengths from 10.5 to 15 mm.

The relation between length (NL) and the number of intestinal melanophores along the left side was compared. No distinct differences in melanophore numbers appeared between species. Both species showed a general tendency for numbers to increase with increase of length. Individual melanophores along the intestine were generally uniform in size and arranged in one straight line on cisco larvae, but variable in size and not arranged in one straight line on whitefish larvae (compare Figs. 10 and 11).

In May 1978, a study was made on the concentration and dispersion of melanophores over the head and back of live lake whitefish larvae. Whitefish larvae were caught at about

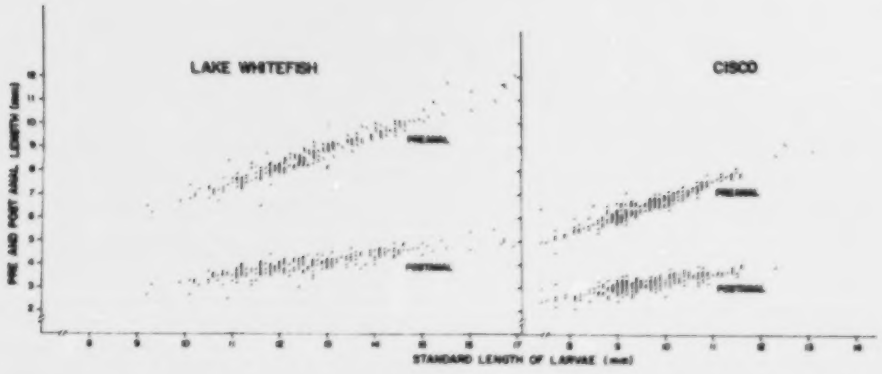

Figure 7. Correlation of standard length (notochord length) with pre- and post-anal lengths of lake whitefish and cisco larvae for 1980.

10 a.m. with tow nets, and immediately transported back to the laboratory where they were transferred into a clear glass bowl and put into a kitchen-type refrigerator for varying lengths of time. These larvae were exposed to two different environments: complete darkness and cooler water. They were captured in water 8 to 10°C, whereas the refrigerator was 3 to 4°C. The results of this treatment are below.

These treatments suggest that darkness causes the concentration of the melanin along the backs of whitefish. Three hours of darkness produced stage 1 melanophores. These results suggest that a diurnal rhythm (= circadian rhythm) occurs in melanophores on the backs of larval lake whitefish (daylight = dispersion, and nighttime = concentration).

Despite all the efforts and experiments described above, there were still specimens that were unidentifiable. No one character separated cisco and lake whitefish larvae but, by combining three characters, separation is relatively complete. These three characters are: (a) notochord length, (b) dorsal pigmentation, and (c) pigmentation above the intestine.

Treatment	Stages* of melanophores on backs
Continuous light outside refrigerator	Specimen 1. (Head) - stages 2, 3 and 4 (Body) - stage 5 except a few 4's
	Specimen 2. (Head) - stages 1, 2 and 3 (Body) - stage 5 except a few 4's
1 hour in dark	Specimen 1. (Head) - stages 3 and 4 (Body)
1 1/2 hours in dark	Specimen 1. (Head) - stages 3 and 4 (Body)
2 hours in dark	Specimen 1. (Head) - stages 2, 3 and 4 (Body)
3 hours in dark	Specimen 1. (Head) - stages 1, 2 and a few 3's (Body)
5 hours in dark	Specimen 1. (Head) - stage 1 and a few 2's (Body)
	Specimen 2. (Head) - stages 1, 2 and a few 3's (Body)

*Stages in the changes of melanophores as defined by Hogben and Slome and illustrated in Parker (1948). Stage 1 melanophores are punctate and concentrated, whereas stage 5 melanophores are reticulate and dispersed.

A KEY TO IDENTIFY SOME LAKE OPEONGO LARVAL FISHES

The larval species collected during this study are only a fraction of the kinds living in Lake Opeongo. Table 2 lists twenty-one species which are known to possess free-swimming larvae. Other species become free-swimming as juveniles, and we would not expect them to be caught with tow nets as larvae, i.e. brook trout, lake trout, splake, and brown bullheads.

The separation of preserved cisco and lake whitefish larvae at all stages of development is still not satisfactory. For example, Pritchard (1930) states, "In differentiating between the "natural" fry of the whitefish [Coregonus clupeaformis (Mitchill)] and those of the cisco [Leucichthys artedi (LeSueur)], one of the most useful characters is the pigmentation". He goes on to discuss how the two larvae can be separated on the basis of the abundance of yellow pigment in live specimens, and on the difference in size when taken on the same day. He said nothing which would help separate formalin preserved specimens. Recently, Hinrichs (1979) described the eggs and larvae of cisco and lake whitefish which were raised in hatchery apparatus. In his "key to the mesolarvae", he indicates that cisco and lake whitefish can be separated (along with total length) by the size and shape of the melanophores along the dorsal finfold (= on the back). In his key (p. 52), he states for lake whitefish that, "Melanophores usually square and paired across dorsal finfold the largest greater than the width of a myomere", while for cisco he states, "Largest ovate melanophores less than or equal to the width of myomere". Our results of light experiments, as recorded in the previous section, suggest that these relationships are not always valid.

The most important part of this key relates to the separation of cisco and lake whitefish. However, the discussions and implications from research on coregonids (Lindsey et al. 1970; McPhail and Lindsey 1970) leads one to believe that additional studies among the coregonid larvae would be disappointing. Faber (1970) shows one length for each of four species, but this study is not adequate to easily identify those larvae. In Europe, Nusslin (1908) has illustrated one length for seven or more coregonid species, i.e. Coregonus albula L., C. fera Jur., C. lavaretus L., C. macropthalamus Nussl., C. marana Bloch., C. oxyrhnchus L., C. steindachneri Nussl., C. sulzeri Nussl., C. wartmanni Bloch., and several unidentifiable specimens. The results of that study are equally inadequate to easily identify species of coregonids.

The present key separates the larvae of burbot, common white sucker, cisco, lake whitefish, Iowa darter, and yellow perch on the basis of easily seen external morphological features. These six fish comprise four families: Gadidae, Catostomidae, Salmonidae (Coregonidae) and Percidae. The traditional guide to the freshwater larval fishes of Ontario has been Fish (1932), but now a more recent guide is available (Auer 1982).

1a. Anus located at middle of body or in last one-half of body length . . 2

1b. Anus located before middle of body, at about 2/5th body length. . . . . .burbot (Lota lota)

2a(1a). Anus located at or very near middle of body 3

2b. Anus located in last one-half of body length, at 2/3rds or 3/4ths body length. 4

3a(2a). Larva possesses air bladder (dorsal concentration of melanophores over air bladder usually visible); lacks a short vertical pigment line at base of pectoral fins; usually common at surface water temperatures of 12 to 18°C. . . . . . yellow perch (Perca flavescens)

3b. Larva lacks air bladder; possesses a short vertical pigment line at the base of pectoral fins, not common in collections. . . . . .Iowa darter (Etheostoma exile)

4a(2b). Larva possesses two complete or incomplete lines of melanophores along back from base of head to tail; possesses two distinct lines of melanophores along ventrad from pectoral fins to tail; lacks a mid-lateral line of melanophores from pectoral fins to tail 5

4b. Not as in 4a. . . . . .common white sucker (Catostomus commersoni)

5a(4a). Larva possesses two complete lines of melanophores along back from base of head to tail; larva has a series of melanophores lying dorsal to intestine which are not uniform in size . . . . . .lake whitefish (Coregonus clupeaformis)

5b. Larva possesses two lines of melanophores along back, normally incomplete or absent from base of head to beginning of finfold; larva has a series of melanophores lying dorsal to intestine which are uniform in size. . . . cisco (Coregonus artedii)

DESCRIPTIONS OF SOME LAKE OPEONGO LARVAL FISHES

Good descriptions of larval fishes are difficult to find in the literature. As larval fishes grow and develop, their morphologies and meristics change dramatically, so a thorough description of larvae at one length may not even be relevant at another length. In addition, the "State of the Art" of larval fish descriptive studies is still at an early stage, as the larvae of many species of fish are still unknown. The illustrations (Figs. 8 to 13) included in this section were drawn utilizing the drawing techniques described in Faber and Gadd (1983).

Descriptions of larval fishes must be used with care for their stages gradually change. During growth, numbers of melanophores increase, fins develop fin rays, the median finfold becomes lost, and various organ systems develop. This account describes in some detail at one length (i.e. that length which is illustrated) six larval fishes that were collected during this study. They include: burbot, white sucker, cisco, lake whitefish, Iowa darter and yellow perch.

BURBOT 4.5 mm NL (Fig. 8)

Burbot larvae are characterized by their small size, short intestine, and lines of melanophores along both dorsal and ventral body. In some bodies of water, these linear series of melanophores appear to be absent (Fish 1932).

Burbot larvae hatch from buoyant eggs at lengths of 3 to 4 mm NL. Complete pigmentless finfold extends dorsally from over air bladder, caudally and then ventrally to a position forward of anus; air bladder with dorsal concentration of melanophores; anus located slightly beyond one-third of body length; air bladder and forward intestine form characteristic elliptical mass behind head; melanophore maculae on internarial, interorbital, and occipital regions; linear series of melanophores along back from occipital to tip of notochord; another linear series extends from anus to tip of notochord; melanophores scattered in gut region; fin rays in dorsal, ventral and caudal fins appear at about 10 mm length.

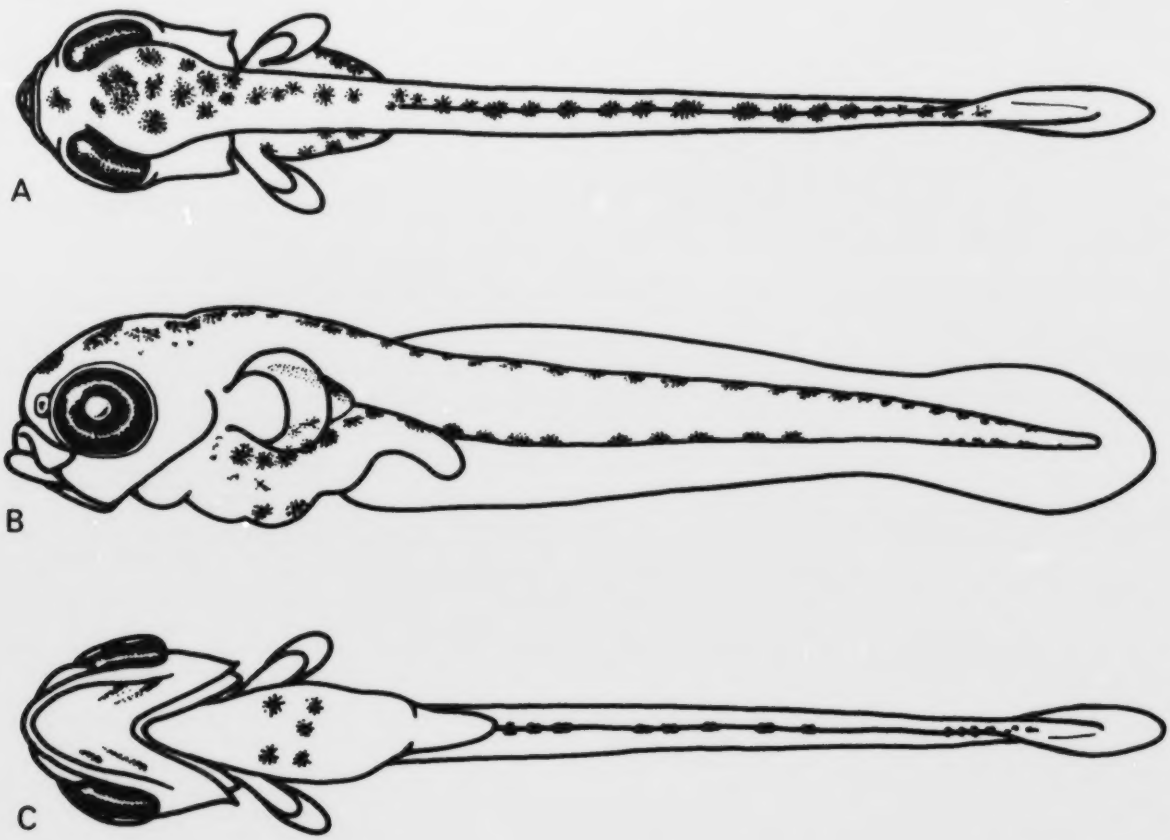

Figure 8. Illustrations of larval burbot, Lota lota, from Lake Opeongo (4.5 mm NL). A, dorsal view; B, lateral view; C, ventral view.

WHITE SUCKER 13.8 mm NL (Fig. 9)

White suckers are characterized by their long, straight intestines, position of anus, and line of melanophores lying mid-laterally above intestine. White sucker larvae hatch at lengths of 8 to 9 mm NL from demersal, non-adhesive eggs.

Pigmentless finfold extends dorsally from above air bladder (about 12th myomere), caudally and a short distance anterior to anus; a long separate section lies anterior of anus and ventral to intestine; compound air bladder with dorsal concentration of melanophores; anus located at about three-fourths of body length; distal portion of intestine long and slender; melanophore maculae on internarial, interorbital and occipital regions; line of melanophores along back from occipital region to caudal peduncle; line of melanophores extends from anus to caudal peduncle; irregular linear series of melanophores extends from heart region to anus; linear series of small melanophores along mid-lateral body extends from pectoral fin to beyond anus (length and number of melanophores increase with growth of larva); fin rays in dorsal, ventral and caudal fins appear at 15 to 16 mm length.

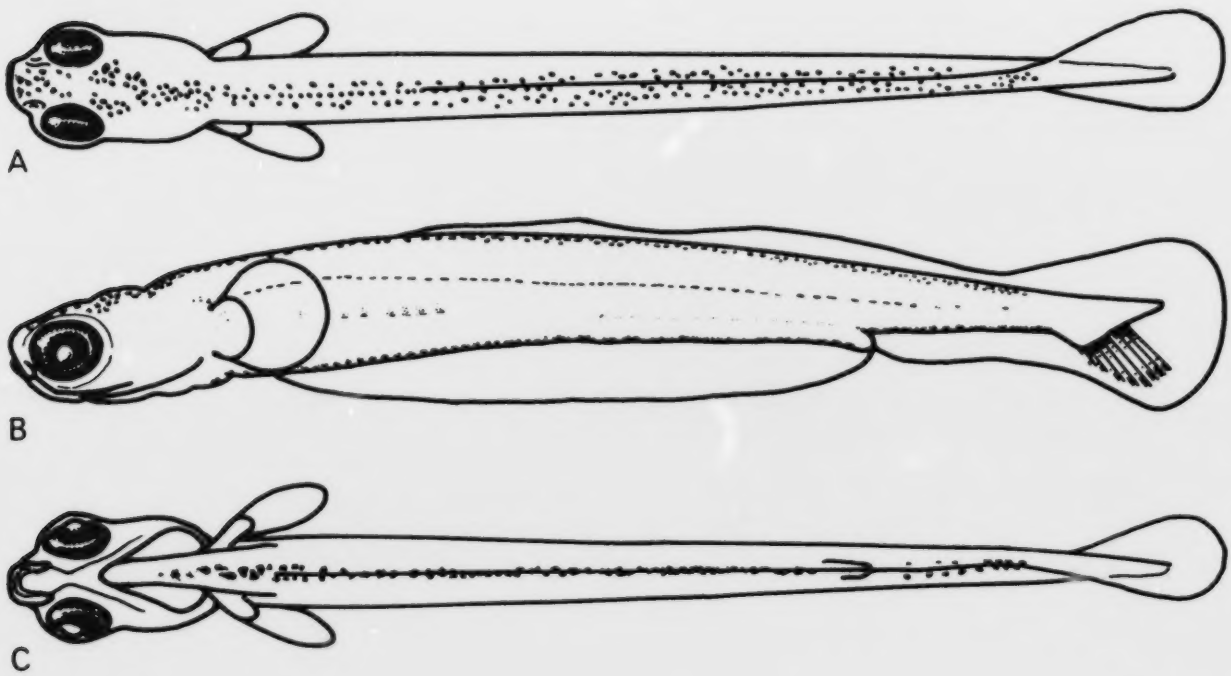

Figure 9. Illustrations of larval white sucker, Catostomus commersoni, from South Bay, Lake Huron (13.8 mm NL). A, dorsal view; B, lateral view; C, ventral view.

CISCO 10.2 mm NL (Fig. 10)

Cisco larvae are characterized by a straight intestine, position of anus, a characteristic line of melanophores along dorsal body, and a characteristic line of melanophores dorsal to intestine. Cisco larvae hatch at lengths of 7.5 to 8.5 mm NL from demersal, adhesive eggs.

Pigmentless finfold extends dorsally from nape, caudally and then ventrally to anus; a separate section lies anterior to anus and ventral to intestine; air bladder not evident; anus located between middle and three-quarters of body length; distal portion of intestine long and slender; few scattered melanophores on interorbital and occipital regions; double line of melanophores along back from occipital region to tip of notochord; this dorsal series is characterized by paired melanophores from tip of notochord to about middle of body and scattered, unpaired melanophores further anterior; paired line of melanophores lying dorsal to intestine are arranged in straight line and are uniform in size; fin rays in dorsal, ventral and caudal fins appear at about 17 mm length.

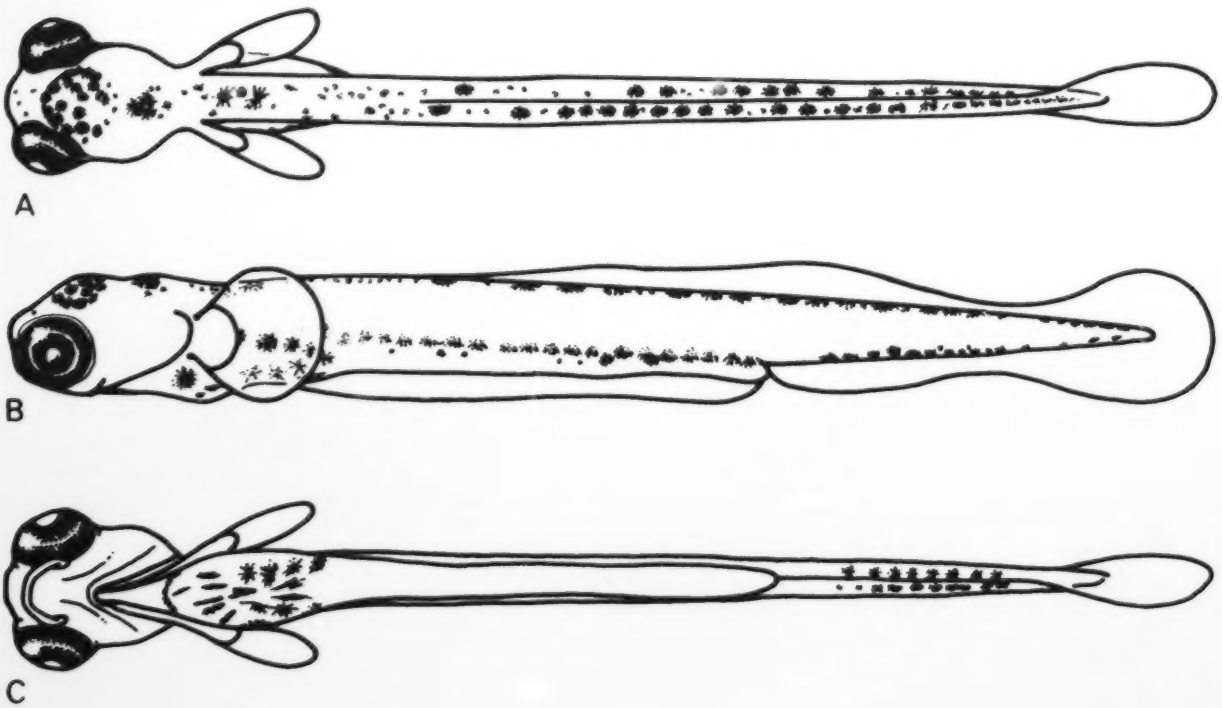

Figure 10. Illustrations of larval cisco, Coregonus artedii, from Lake Opeongo (10.2 mm NL). A, dorsal view; B, lateral view; C, ventral view.

LAKE WHITEFISH 12.2 mm NL (Fig. 11)

Lake whitefish larvae are characterized by a straight intestine, position of anus, a characteristic line of melanophores along dorsal body and a characteristic paired line of melanophores dorsal to intestine. Lake whitefish larvae hatch at lengths of 9.5 to 10.5 mm from demersal, slightly adhesive eggs.

Pigmentless finfold extends dorsally from nape, caudally and then ventrally to anus; a separate section lies anterior to anus and ventral to intestine; air bladder not evident; anus located between middle and three-quarters of body length; distal portion of intestine long and slender; melanophore maculae on occipital region; double line of melanophores along back from occipital region to tip of notochord; this dorsal series is characterized by paired melanophores from tip of notochord to occipital region with occasional portions of the series absent; paired line of melanophores lying dorsal to intestine which are arranged in a line but not uniform in size; fin rays in dorsal, ventral and caudal fins appear at about 18 mm length.

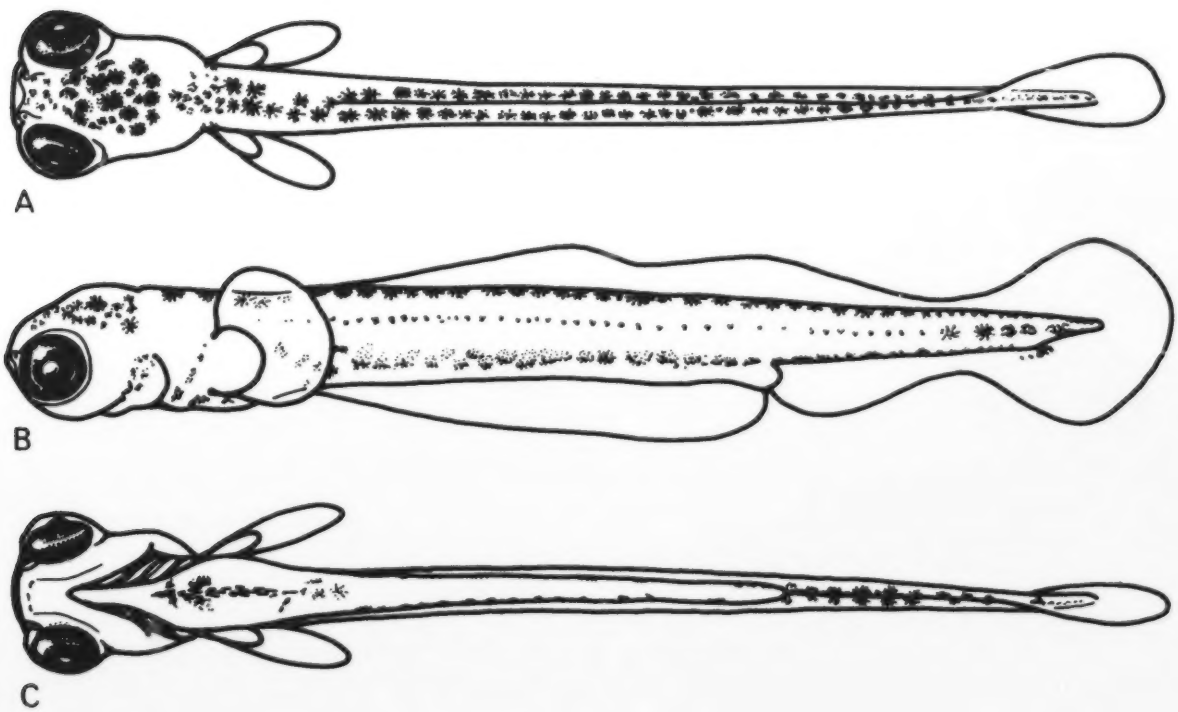

Figure 11. Illustrations of larval lake whitefish, Coregonus clupeaformis, from Lake Opeongo (12.2 mm NL). A, dorsal view; B, lateral view; C, ventral view.

IOWA DARTER 8.2 mm NL (Fig. 12)

Iowa darter larvae are characterized by lack of an air bladder, small size and short vertical pigment line at base of each pectoral fin. Iowa darter larvae hatch from demersal eggs at lengths of 3 to 4 mm.

Pigmentless finfold extends dorsally from over intestine (about 15th myomere), caudally and then ventrally to the anus; a smaller separate section lies anterior of anus and ventral to intestine; no air bladder; anus located at middle of body; distal portion of intestine long and slender; entire dorsal body free of melanophores up to about 10 mm-length; irregular line of melanophores extends from anus to caudal peduncle; parallel series of melanophore maculae lying ventro-laterally between myomeres occur above intestine and posterior to anus; pair of short vertical pigment lines at base of each pectoral fin; fin rays in dorsal, ventral and caudal fins appear at about 8 mm length.

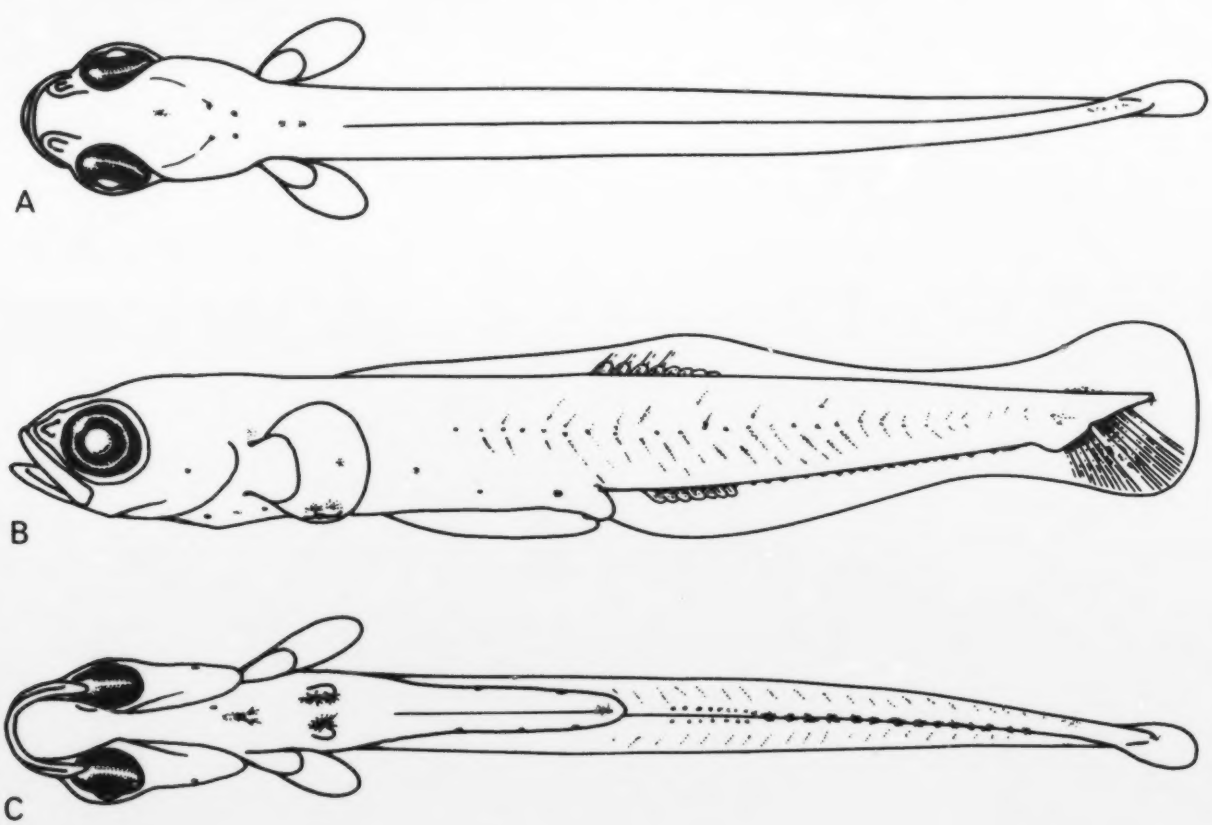

Figure 12. Illustrations of larval Iowa darter, Etheostoma exile, from Lac Heney, Quebec (8.2 mm NL). A, dorsal view; B, lateral view; C, ventral view.

YELLOW PERCH 10.4 mm NL (Fig. 13)

Yellow perch larvae are characterized by a straight intestine, an air bladder, position of anus, and melanophore maculae lying ventrolaterally between myomeres. Yellow perch larvae hatch from demersal eggs at lengths of 5 to 6 mm NL.

Morphological characteristics include: pigmentless finfold; separate section of finfold lies anterior to anus and ventral to intestine; air bladder with dorsal concentration of melanophores; anus located at middle of body; distal portion of intestine long and slender; entire dorsal body free of melanophores up to about 12 mm length; irregular line of melanophores extends from anus to caudal peduncle; a parallel series of melanophore maculae posterior to anus lying ventro-laterally between myomeres; a few melanophores scattered around intestine; fin rays in dorsal, ventral and caudal fins appear at about 12 mm length.

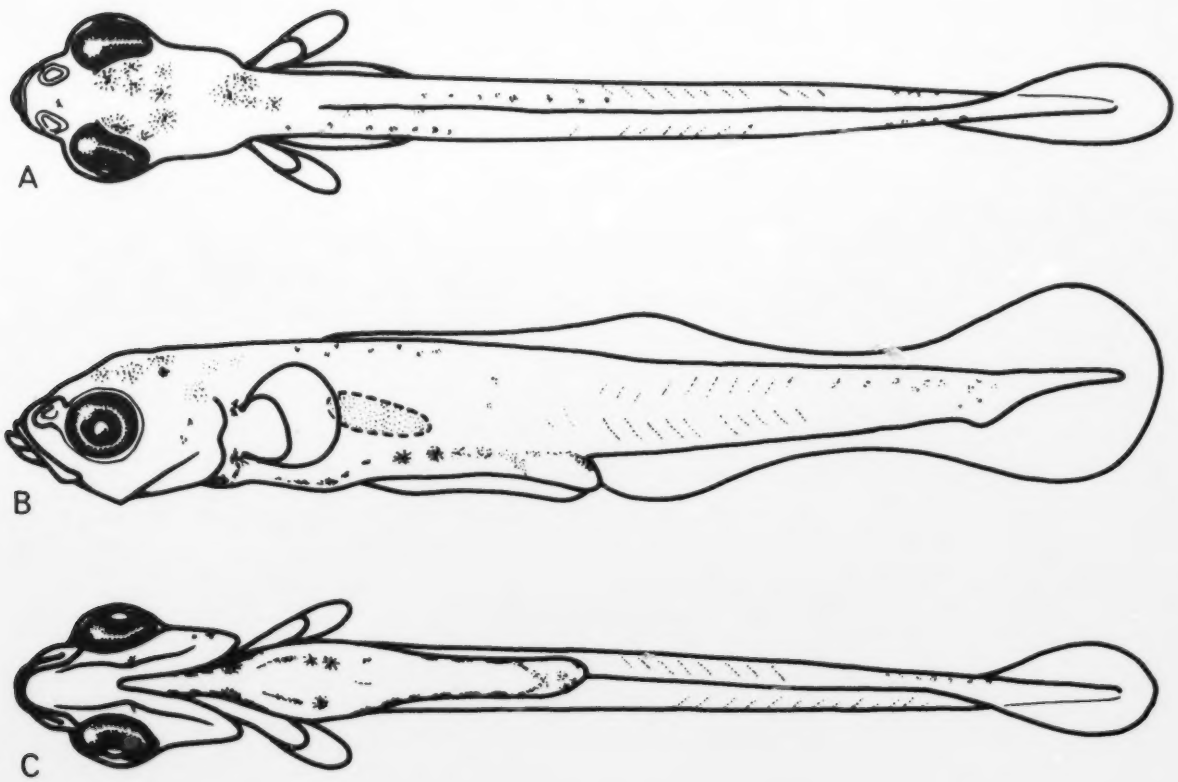

Figure 13. Illustrations of larval yellow perch, Perca flavescens, from Lake Opeongo (10.4 mm NL). A, dorsal view; B, lateral view; C, ventral view.

THE EARLY LIFE OF LAKE WHITEFISH

Lake whitefish spawn in the fall during decreasing water temperatures. In Lake Opeongo, spawning can begin as early as October 31 and continue as late as mid-November. Peak spawning normally occurred between 8-15 of November during the last decade. A known whitefish spawning area (Lucky Strike) has also been used for spawning by several other fall and winter spawning species (burbot, cisco and lake trout) (Hindley 1982; Cucin unpubl. data). Whitefish spawning areas in Lake Opeongo were generally located along exposed shores or points, and along shores on islands 10 to 50 m from shore; depth of water varied from 3 to 5 m. Substrate consisted largely of gravels, granitic boulders and broken rocks. Studies in other lakes have shown that whitefish utilize similar shoreline locations as well as offshore reefs and shoals in depths up to 10 m. Substrates varied from flattened limestone and boulders to extensive limestone shelves (Hart 1930; Hoagman 1973; Goodyear et al. 1982). Literature reports indicate that water temperatures during spawning varied from 8°C down to 3°C.

The eggs of lake whitefish possess colorless egg membranes which are slightly adhesive and contain amber colored yolk materials with numerous oil globules (Hinrichs 1979). Ripe but unfertilized eggs from the ovaries of Lake Opeongo whitefish ranged from 1.9 to 2.1 mm in diameter, while water-hardened eggs measured 2.4 to 2.7 mm. Hart (1930) reported ovarian eggs of 2.3 to 2.4 mm in diameter, while water-hardened eggs were 3.0 to 3.2 mm. Hinrichs (1979) reported water-hardened eggs which measured 2.8 $\pm$ 0.2 mm (range 2.3 to 3.0 mm). Eggs from Lake Opeongo whitefish were recorded to have the least wet and dry weights among populations from several lakes (Ihssen et al. 1981).

Whitefish eggs rest in rocky crevices, in water temperatures from 1.0 to 8°C for four to six months. Ihssen et al. (1981) reported that lake whitefish eggs from Lake Opeongo hatched in 160 days under laboratory conditions, and in 175 days in the lake. The incubation period of eggs from Lake Opeongo was the longest of four lakes, as reported in Ihssen et al. (1981).

When lake whitefish larvae free themselves from their egg capsules, they are able to begin swimming immediately because of their small yolk reserves (Tait 1960; Hinrichs 1979). The available data suggest that dates of emergence from spawning substrates in Lake Opeongo varied from year to year, and possibly from area to area. Collins' emergent fry traps caught both emerging lake whitefish and lake trout on May 19 and 23, 1979 (MacLean unpubl. data). Sizes of these recently emerged whitefish for May 23 are 11.5 to 12.5 mm ($\bar{x}$ = 11.86 mm, n =20). In South Bay, Lake Huron, Collins (1975) reported that lake whitefish emerged at different periods of time during different years. Table 11 shows significant differences in the beginning and duration of emergence.

After emergence, larval whitefish swim up to the epilimnetic region to begin their next stage of life. The first whitefish in Lake Opeongo taken in tow nets were caught close to the surface over water depths of 1.5 to 10 m. They measured 11.3 $\pm$ 0.6 mm in length (NL) and possessed little yolk materials. Many were taken near known whitefish spawning areas. Several points with rocky substrate, that extended as shoals 30 to 50 m from shore down to a depth of 10 m, occasionally produced larval whitefish up to the latter half of May. Surface tows over deeper waters away from shore were usually less productive. Lake Opeongo whitefish were smaller at first capture than that reported for other Ontario fish populations (Ihssen et al. 1981).

Table 11. Number[1] of lake whitefish larvae captured during the act of emergence from a spawning ground in South Bay over a five-year period. Collins' emergent fry traps were set over the spawning substrate in a grid pattern (Collins 1975).

20 Traps		20 Traps		35 Traps		20 Traps		19 Traps	
1971		1972		1973		1975		1976	
Date	Larvae	Date	Larvae	Date	Larvae	Date	Larvae	Date	Larvae
May 14	3	May 14	2	Apr 25	14	May 8	2	Apr 28	2
May 17	7	May 16	4	Apr 30	10	May 13	8	May 3	4
May 21	9	May 19	2	May 3	21	May 16	4	May 5	1
May 26	2	May 21	2	May 7	7	May 18	3	May 10	2
May 30	0	May 23	7	May 11	7	May 24	2	May 12	1
		May 26	2	May 15	3	May 26	4	May 14	1
		May 30	0	May 21	3	Jun 2	1	Jun 9	0
				May 23	3	Jun 24	0		
				May 30	0				

[1]Unpublished data kindly made available by John J. Collins.

The spatial distribution of larval whitefish in surface waters in Lake Opeongo is similar to that observed for other lakes (Hart 1930; Faber 1970; Reckahn 1970; Hoagman 1973; DesJardine 1979; Loftus 1982). Hart (1930), working on the Bay of Quinte, Lake Ontario, indicated that on hatching, larval whitefish came to the surface over the spawning grounds where they remained a few days before moving towards shore. There they concentrated in shallow water and later moved out from shore, remaining near the surface for a few days before moving to the bottom in medium water depths. Their inshore habitat was mainly in and around reed beds and only occasionally over rocky substrate but, in every instance, they were found in shallow water in fairly well protected locations. Faber (1970), using a tow net sled in South Bay, Lake Huron, found that larval whitefish "appeared to congregate along steep, but not precipitous, shorelines", over a substrate characterized as "a ribbon of boulders, rocks and pebbles from 2 to 20 m wide". Although the net was towed along the substrate at depths from 1 to 10 m, the most productive depths were less than 3 m. Hoagman (1973) caught larval whitefish in Green Bay, Lake Michigan, at the surface in inshore areas and bays over water depths of 3 m or less. His "index" stations varied from a shallow, well protected bay with areas of rocks and emergent vegetation, to more exposed shorelines comprised of sandy rock rubble or rocky shelves with massive boulders and slabs of rock. In Lake Simcoe, Ontario, DesJardine (1979) collected larval whitefish over all water depths and at considerable distances from shore, but most were in nearshore areas. His index stations were generally characterized by relatively clear water, absence of aquatic vegetation, a substrate consisting of rubble and limestone flats in shoal areas, and sand or mud at offshore sites. Loftus (1982) found that newly hatched larval whitefish and cisco could be taken over rock shoal areas. He stated that, "There were no apparent differences in the hatching times of these species, and they were usually taken together in catches". Reckahn (1970) captured post-larval whitefish in South Bay of Lake Huron on one occasion near emergent vegetation at water temperatures close to 17°C.

Larval whitefish are normally dispersed throughout lakes in near-surface waters with concentrations found in certain areas. The extremely variable catch data for tow net catches of lake whitefish is no doubt a result of annual differences in survival of eggs and larvae in combination with active dispersal. As whitefish larvae search for suitable and preferred habitats in which to live, their densities decline as the distance from hatching sites increase. Our sampling program did not provide any evidence for the causes of dispersion, but we suggest that the following factors are important: surface wind-driven currents, irregular distribution of food items, innate dispersive behaviour, a search for warm water, an innate "wanderlust", and avoidance of predators.

The growth gradient (curve) of larval fish has been described as being of several phases, generally an initial slow growth phase followed by one or two faster growth phases. In 1980, for Lake Opeongo, the first phase lasted for 21 days. Similar data were plotted for the early growth of lake whitefish in the Bay of Quinte and Green Bay (Fig. 14). The initial rates of growth for the three areas are slightly different, with Lake Opeongo whitefish displaying the second fastest rate of growth. A comparison of the growth curves of whitefish (Fig. 14), with the 3 growth curves for three marine species (Houde and Schekter 1981) which were determined by three prey concentrations, strongly suggests that food availability is an important factor in the early growth of fish. The growth curves shown in Fig. 14 best resemble the growth curve in which the prey concentration was the lowest. The low rate of initial growth of whitefish is probably a result of low food concentrations compounded by low water temperatures.

After a period of time in the epilimnetic region where they feed on planktonic invertebrates, young whitefish move to the littoral region to begin feeding on benthic inverte-

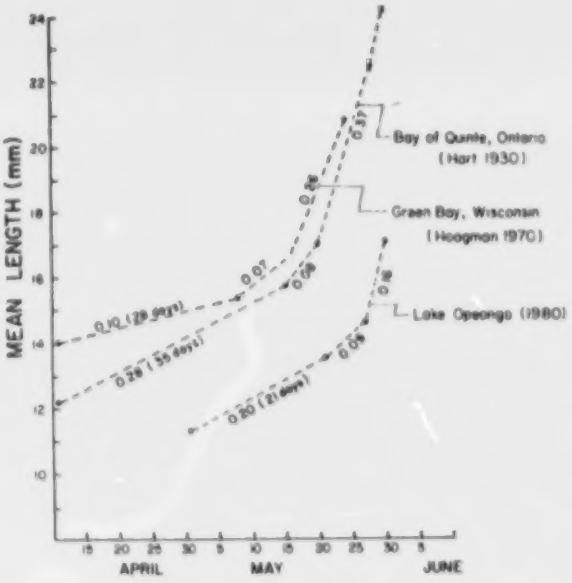

Figure 14. Relative growth of larval whitefish through several growth periods in Lake Opeongo (1980), Bay of Quinte, Ontario (Hart 1930) and Green Bay, Wisconsin (Hoagman 1973). Numbers on graph are relative growth values calculated as the length increment between two time periods divided by the length at the first time period (Everhart and Youngs 1981).

brates. Larval whitefish are unavailable to tow nets at surface temperatures over 12°. This move to a deeper and more benthic way of life, with more dependence upon the lake bottom, probably occurs during June in Lake Opeongo.

THE EARLY LIFE OF CISCO

Cisco spawned last among the coregonids in Lake Opeongo, beginning in mid-November and continuing until well into December. Between 1973 and 1982, few "ripe" female cisco were caught prior to November 14, but both ripe and spent females were regularly taken after this date. However, adverse weather conditions generally prevailed at that time making it difficult to determine actual spawning periods or locations. Under-the-ice gill net samples taken on December 5, 1974, December 16, 1976, and November 25, 1980 showed that half the female ciscos were still ripe or only partly spent, indicating that some egg deposition had taken place and was probably still occurring under the ice. Brown and Moffett (1942) reported that cisco spawning peaked on December 14, 1939, in Swains Lake, Michigan. Swains Lake froze over completely later that same night.

In Lake Opeongo, egg deposition by cisco was never observed, but ripe and spent cisco were taken at a number of widespread locations, including some in which ripe whitefish and round whitefish (Prosopium cylindraceum) had previously been taken. Hindley (Ms 1982), working under the ice on a major lake trout spawning area in the East Arm of Lake Opeongo (March 19, 1980), recovered cisco eggs along with eggs and egg shells of lake whitefish, burbot and lake trout. This large spawning area, located 30 to 50 m from shore at a depth of 3 to 5 m, has a substrate that consists largely of fine gravels, granitic boulders and broken rock, covered by a light layer of silt. In the Bay of Quinte, Lake Ontario, cisco spawned on a submerged reef (Hogsback Reef) at a depth of only 2.5 to 3.0 m (Pritchard 1930). The substrate on the reef area consisted mainly of flat stones 5 to 91 cm in diameter, covered with a layer of fine silt. Cisco eggs were found in the crevices and under stones. Temperatures during the spawning period ranged down to 3.3°C. In Lake Opeongo, the occurrence of ripe and spent cisco in numerous areas, and the widespread distributon of larval cisco with large yolk sacs early in the spring, suggest that cisco utilize more areas and possibly a greater variety of substrates for spawning than do whitefish.

Cisco eggs have been described as slightly adhesive, with colorless egg membranes and yellow to amber yolk materials which contain numerous spherical oil globules (Hinrichs 1979). Unfertilized cisco eggs from Lake Opeongo ranged in diameter from 0.95 to 1.57 mm, with a mean of 1.23 mm, n = 21. Live, water-hardened eggs averaged 2.1 mm (Hinrichs and Booke 1975) and preserved, water-hardened eggs ranged from 2.0 to 2.55 mm from Great Lakes stock (Fish 1932). Spherical yolk materials (oil globules) within these eggs averaged 1.8 mm in diameter (Fish 1932).

The incubation period for Lake Opeongo cisco was not determined, but a minimum incubation period might be inferred by using, as the start of most egg deposition, the date when half the females in catches were in the spent condition (generally November 25). The third day after ice break-up (the earliest date that larval cisco were taken) might be inferred as the beginning of larval emergence. For 1978 to 1981 then, the minimum incubation period would have varied from 155 to 175 days. Colby and Brooke (1970) reported that, "The average incubation time from fertilization to 50% hatch varied from 37 days at 9.9 to 10.3°C to 236 days at 0.5°C, from specimens taken from Pickerel Lake, Michigan. John and Hasler (1956), in their study of hatching and survival of cisco eggs from Lake Mendota, Wisconsin, showed that increased light during late incubation stimulated the movement of embryos. This action by embryos close to hatching probably speeds up larval emergence. We first observed cisco larvae in Lake Opeongo 3 to 5 days after ice break-up, and we believe that the disappearance of the ice cover may well be important in assisting the hatching process. However, factors other than light may also influence the hatching process. In 1983, and also in 1984, cisco larvae were observed and captured through holes in the ice, four to five weeks prior to ice break-up in Drag Lake, Haliburton County, Ontario (D. Loftus pers. comm.). John and Hasler (1956) generalize that, "The dates of hatching are apparently unrelated to the dates of spawning, the dates of formation and departure of the ice, or the temperatures of the water prior to the freeze-over".

After emergence from the spawning substrate, larval ciscos become free-swimming and swim up toward the surface (Hinrichs 1979). This appears to be an important period of dispersal in the lives of Lake Opeongo ciscos. These larvae were collected most often along shallow inshore areas in the same areas utilized by whitefish and perch; few were taken over deep offshore areas. DesJardine (1979) stated that in Lake Simcoe, "Larvae caught in offshore tows could be as abundant as in nearshore catches, but that larvae located offshore appeared to exist in pockets or concentrations". We believe that this spatial distribution, in contrast with that in Lake Opeongo, might be a result of Lake Simcoe's numerous offshore spawning shoals; in Lake Opeongo, ciscos utilize shoreline spawning areas more often. These differences might be influenced by differing lake morphologies.

During periods of abundance, larval ciscos were observed in Lake Opeongo actively swimming about 30 cm below the water's surface (epilimnetic region). They were observed and collected along shallow inshore areas, but never in vegetation. Pritchard (1930) stated that in the Bay of Quinte, "The habitat of the fry is amongst the reeds along shores of the protected bays". In Lake Opeongo, three special walking excursions were made along suitable shores near index area D to search for them. None were sighted, although schools of larval white suckers and cyprinid minnows were readily observed. These conflicting results suggest that extensive surveys in shallow weedy bays still need to be performed.

Larval cisco from Lake Opeongo ranged in size from 9.0 mm to 12.5 mm, but the mean length for each sampling day over the period of May 1 to May 30 remained relatively constant, between 9.5 to 10.0 mm (Fig. 15). This constant length was probably due to the continual recruitment of recently hatched cisco, emigration from the area by older fry, and the reduced efficiency of the gear for older larvae. Growth of larval cisco in the Bay of Quinte, from May 8 to 30, after an initial mean length of 10.3 mm, steadily increased from 12.5 to 18.1 mm (Pritchard 1930). We did not capture larval cisco much beyond 12 mm in Lake Opeongo. Possibly these larvae were living in shallow weedy bays which could not be sampled with tow nets.

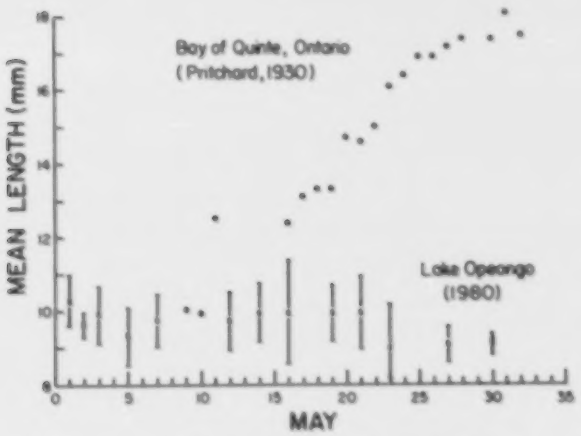

Figure 15. Seasonal growth of larval cisco in Lake Opeongo (1980) and the Bay of Quinte, Ontario (Pritchard 1930).

THE EARLY LIFE OF YELLOW PERCH

Yellow perch spawn in Lake Opeongo during the latter half of May. Accordian-shaped egg masses have been found attached to the branches of sunken trees at depths of 1 to 3 m, as well as directly on sand and fine gravel substrate. These masses were most often observed on the south facing shores of protected bays and islands. Temperatures during this period ranged from 12 to 15°C (Somers unpubl. data). These results are consistent with other published observations where authors reported that spawning of perch could occur as early as late February or early March, but usually occurred between mid-April and late May. "Perch eggs are extruded in long 'accordian folded' strands about 1 1/2 inches thick" (Mansueti 1964). Egg masses were observed in these lakes at depths of 0.5 to 3.0 m, attached to the branches of submerged brush, trees, beds of rooted aquatic vegetation, artifacts (dock pilings, etc.) or directly on sand and fine gravel substrates. Temperatures during spawning ranged from 7 to 11°C (Weber and Les 1982).

Perch eggs are semi-transparent, the yolk being light grey to clear amber in color. Preserved water-hardened perch eggs from Lake Opeongo were semi-transparent, light amber in color and averaged 2.5 mm in diameter. Mansueti (1964) reported in her study that the fertilized water-hardened eggs averaged 2.26mm (range 1.84 to 2.81 mm) in diameter.

Incubation times ranged from 8 to 15 days but, depending on temperature, lasted as long as 20 days (Harrington 1947; Echo 1954; Herman et al. 1959; Muncy 1962; Wong 1972; Scott and Crossman 1973; Weber and Les 1982). In Lake Opeongo, perch eggs were observed on the bottom as early as May 18, and larval perch were taken by tow nets in these same areas on May 28, suggesting a minimum incubation period of 10 days. Temperatures ranged from 12 to 15°C. Newly hatched larval perch range from 5.0 to 6.0 mm (Mansueti 1964; Henderson 1977; Weber and Les 1982).

Larval perch were first taken in inshore littoral areas and, shortly afterward, were taken up to 300 or 400 m from shore in the epilimnetic zone. Peak numbers of larval perch occurred in mid-June, followed by a decline and/or complete absence by early July. These results are similar to those reported for Oneida Lake (Houde 1968; Noble 1968), and West Blue Lake (Wong 1972; Henderson 1977). The decline and/or absence of larval perch in catches in mid-July was attributed by Noble (1968) and Henderson (1973) to two factors: (1) the larger larval perch avoided the tow nets; and (2) perch gradually moved deeper in the shallow littoral zone.

Only one index area showed evidence of a gradual increase in numbers offshore in the limnetic region over numbers in littoral areas. An actual case of offshore dispersal was confirmed in a later, more intensive sampling program of Squaw Bay (index area E). In Lake Opeongo, young perch were observed living in the littoral area throughout July and August. Wong (1972) and Henderson (1977) showed that after hatching, most of the larval perch were

first collected in the inshore littoral zone (from the surface down to 3 m), and later were caught up to 400 m away from shore.

Houde (1968) and Noble (1968) suggested that dispersal was mainly passive due principally to the effects of winds, turbulence and current patterns in the lake. Henderson (1972) and Wong (1972), however, suggested that in West Blue Lake this movement was more than just passive, but was a behavioral response to temperature and food availability. Faber (1967) suggested that young fish actively dispersed into limnetic waters, possibly for protection against predators, or the movement might possibly be an "innate" wanderlust.

The occurrence of larval perch is closely related to surface water temperatures. In Lake Opeongo, they appeared after the temperature attained about 13°C (Fig. 4). Faber (1967) showed that larval perch first appeared in two small lakes at 13°C in mid-May. In general, yellow perch larvae occur in May in shallow lakes which warm up quickly, whereas they occur in June in deep lakes, such as Lake Opeongo, which warm up more slowly. The occurrence of two peaks of hatching is the result of differential warm-up within the lake. Fuiman (1982) recorded one peak in mid-May and a second peak in early July in Lake Michigan. He explained that the first peak was hatched in a shallow lake (Pigeon Lake) adjacent, but connected to Lake Michigan.

Growth of larval perch appeared to vary between different areas of the lake. Henderson (1977) described growth of larval perch as occurring in two stanzas. The first stanza was a slow growth period that encompassed the period of dependence on yolk to the initial feeding on small zooplankters (i.e. from hatching to the beginning of movement into the pelagic zone when length was 9 to 10 mm). The second stanza had a higher growth rate, covering the period from the early pelagic phase to the end of the summer. This latter stanza is coincident with the start of intensive feeding on larger zooplankters (length at the end of this stage was 25 to 30 mm). In Lake Opeongo, lengths for corresponding stanzas were slightly less.

Temperature, as well as food, is important in the growth of perch (Blaxter 1969; Henderson 1977). In Lake Opeongo, results for 1979 and 1980 demonstrated the influence of temperature. Growth to early June was similar in both years, but it increased more rapidly through June in 1979 than in 1980. Surface temperatures in late May of 1980 were higher than for the corresponding period in 1979 (Fig. 6). Through most of June 1979, temperatures increased steadily, whereas in 1980, surface temperatures declined in mid-June before increasing again. These cooler temperatures in June 1980 appeared to have resulted in a substantially lower growth rate and smaller average size, compared to 1979.

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The specimens of larval fishes have been submitted to the National Museum of Natural Sciences for accession into the National Ichthyology Collection.

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